Investigating the genetics and agronomic traits associated with elevated grain Zn concentration in wheat

A thesis submitted in fulfillment of the requirement for the degree of

Doctor of Philosophy

By

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This thesis is dedicated to my family Rashid, Junaid, Nadir, Asjid and Rubab whose moral support in many ways and over many years helped me to pursue my goals.

Abbreviations

PS : Phytosiderophores

NA : Nicotianamine

G x E : Genotype x Environment

EDXRF : Energy Dispersive X-ray Fluorescence

AAS : Atomic Absorption Spectrometry

CI : Confidence Interval

DH : Double Haploid

HPAN : HarvestPlus Advance Nursery

ICP-OES : Inductively Coupled Plasma–Optical Emission Spectrometry

LOD : Logarithm of the odds

QTL : Quantitative trait loci

XRF : X-ray Fluorescence spectrometry

MAS : Marker Assisted Selection

CIMMYT : International Maize and Wheat Improvement Center

SARDI : South Australian Research and Development Institute

TGW : Thousand Grains Weight

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Abstract

Biofortification of wheat and other food crops with Zn is an important and high-priority research issue. This project focused on the genetic and agronomic factors that control grain Zn concentration in wheat. Understanding this may make it possible to increase Zn in wheat for biofortification purposes. Specific aims were (i) to identify wheat genotypes that differ in grain Zn concentration. (ii) to understand agronomic traits that are relevant to Zn accumulation in grain (iii)) to conduct mapping studies to find genetic loci which confer high Zn concentration.

A number of genotypes of Berkut x Krichauff were grown to investigate Zn concentration and its relationship with morphological traits. This study confirmed a negative association of grain yield with Zn concentration. Low Zn lines which had low Zn concentration in the field, had high grain Zn concentration in the glasshouse which was considered to be due to dust contamination and a modified Kett mill, has been used to eliminate dust contamination but the results have shown that Fe concentration and ranking are greatly affected by soil contamination, whereas Zn concentration and ranking are not. A cleaning method was shown to be an important step prior to analysis for precise QTL analysis. The inconsistent results of low Zn lines were probably not a consequence of soil contamination. The results were due to inconsistent Zn levels in the grain itself. Because there was no correlation between field trials and glasshouse results, the focus of study was switched to the genetics of grain Zn concentration.

There was a need for increased knowledge of the genetic basis of Zn density in wheat and QTL analysis is considered a powerful strategy to do this. ICP-OES analysis is mostly used for QTL analysis which is very expensive. XRF was proposed as an alternate method for elemental analysis. Importantly, despite the greater errors of XRF results than ICP-OES results, XRF results allowed the identification of the same number of QTLs as ICP-OES, in the Berkut x Krichauff population in year 2007.

Berkut x Krichauff 2009, Excalibur x Kukri, and Kukri x RAC 875, populations were used for validation. In Berkut x Krichauff populations, two QTLs for Zn, located on 7A (LOD 4.9) and 5D (LOD 3.9), were identified and the QTL on 5D was a new one not reported in any published studies, whereas the QTL on 7A was also found in two other mapping populations and in four other studies reported in literature. These two new Zn QTLs were not co-located with grain size while in the other two populations, Zn QTLs were found but co-located with grain size and the Zn-dense trait was associated with a smaller grain size and hence a concentrating effect. This trait is not desirable for plant breeding as it is associated with a lower yield. The Zn QTLs not associated with grain size can be used to further develop genetic markers which plant breeders can use to speed up the breeding of genotypes with a higher level of grain Zn.

Acknowledgements

This project has been completed under the supervision of Associate Professor James Stangoulis, Dr. Nick Paltridge and Prof. Robin Graham.

I would like to express my hearty thanks to A. Prof. James Stangoulis for untiring support, continuous guidance, steady encouragement, advice and endless enthusiasm for preparation and write up of this manuscript. I would like say my many thanks Prof. Robin Graham for his great help in correction of this write up. I am also very grateful for all the suggestions and constructive criticism offered by Dr. Nick Paltridge. It was an immense chance for me to learn and work with them.
I would like to thank Dr. Lam Bao Huynh for the help with mapping studies and Lachlan Palmer for his help. I wish to thank Dr. Nick Paltridge for statistical advice and analysis.

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.